National Weather Service

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Outline

Part I: Fundamentals

- Radar Principles
- Doppler Velocity Interpretation
- SRV vs Base Velocity
- Pre-storm Environment Analysis

Part II: Radar/Storm Interpretation

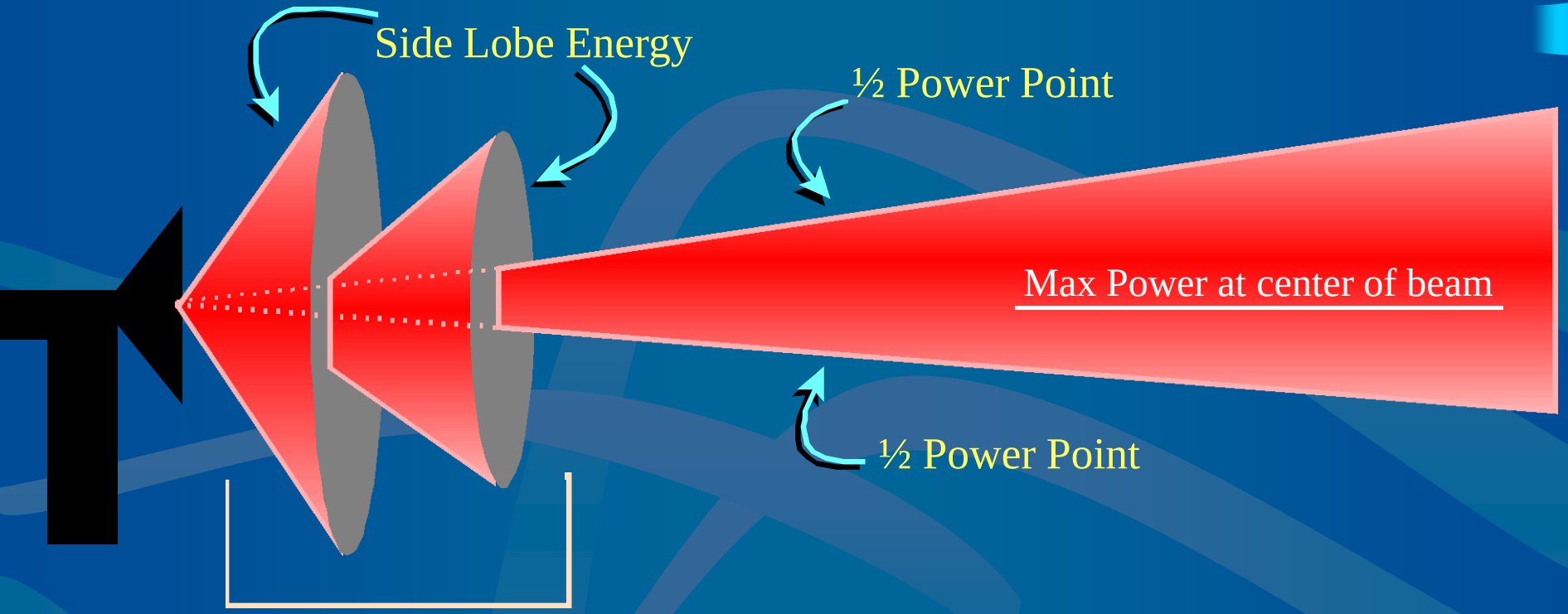
- Thunderstorm Spectrum
- Severe Storm Generalities
- Les Lemon Criteria
- Pulse Storms
- Multicell Clusters/Lines
- Supercells

Part III

- Build 10 - New TVS Algorithm

Radar Basics

Beam Power Structure



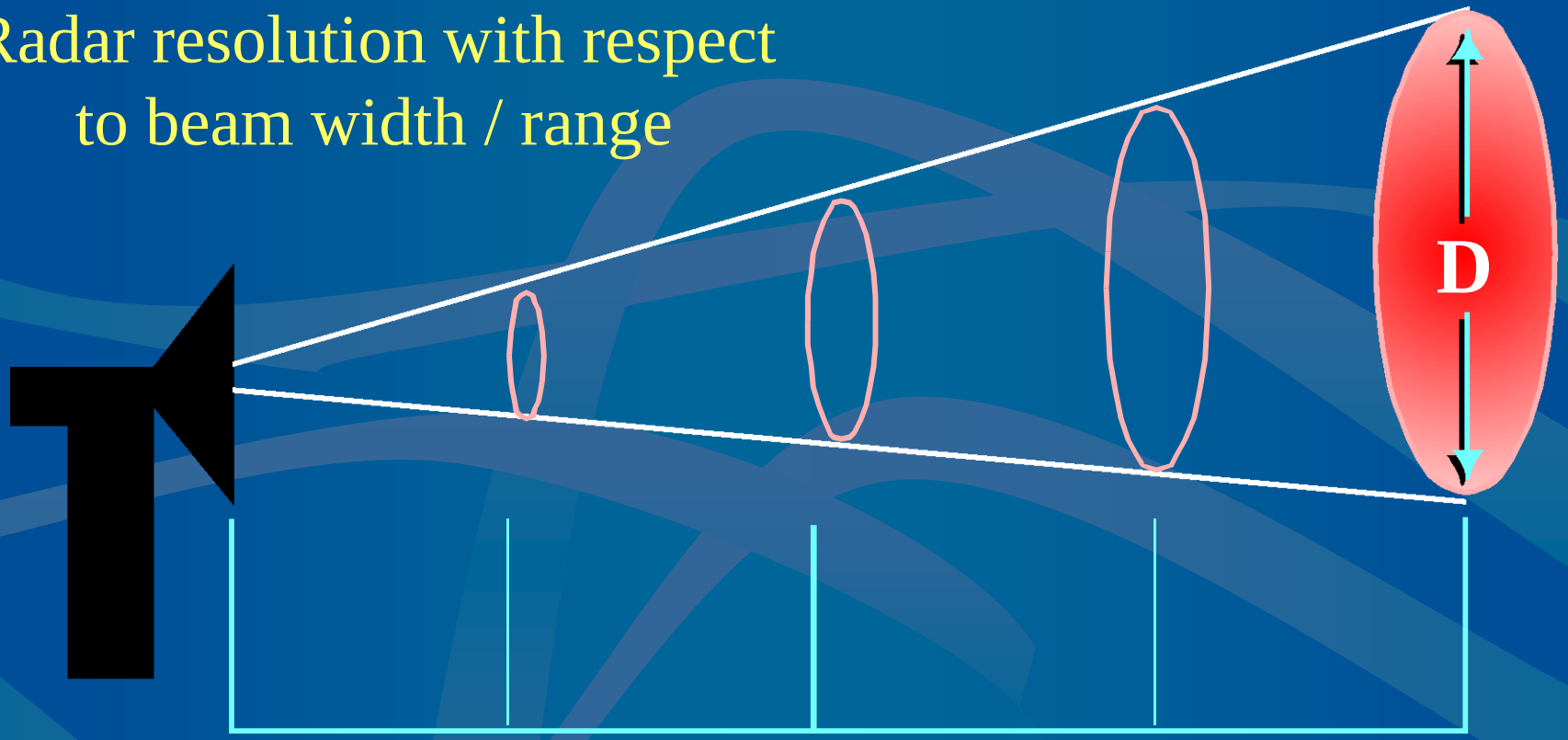
Side Lobes cause most of the clutter in close proximity to the radar

The Radar Beam is defined by the half power points

.96 Degree Beam Resolution

D = Beam Width

Radar resolution with respect to beam width / range



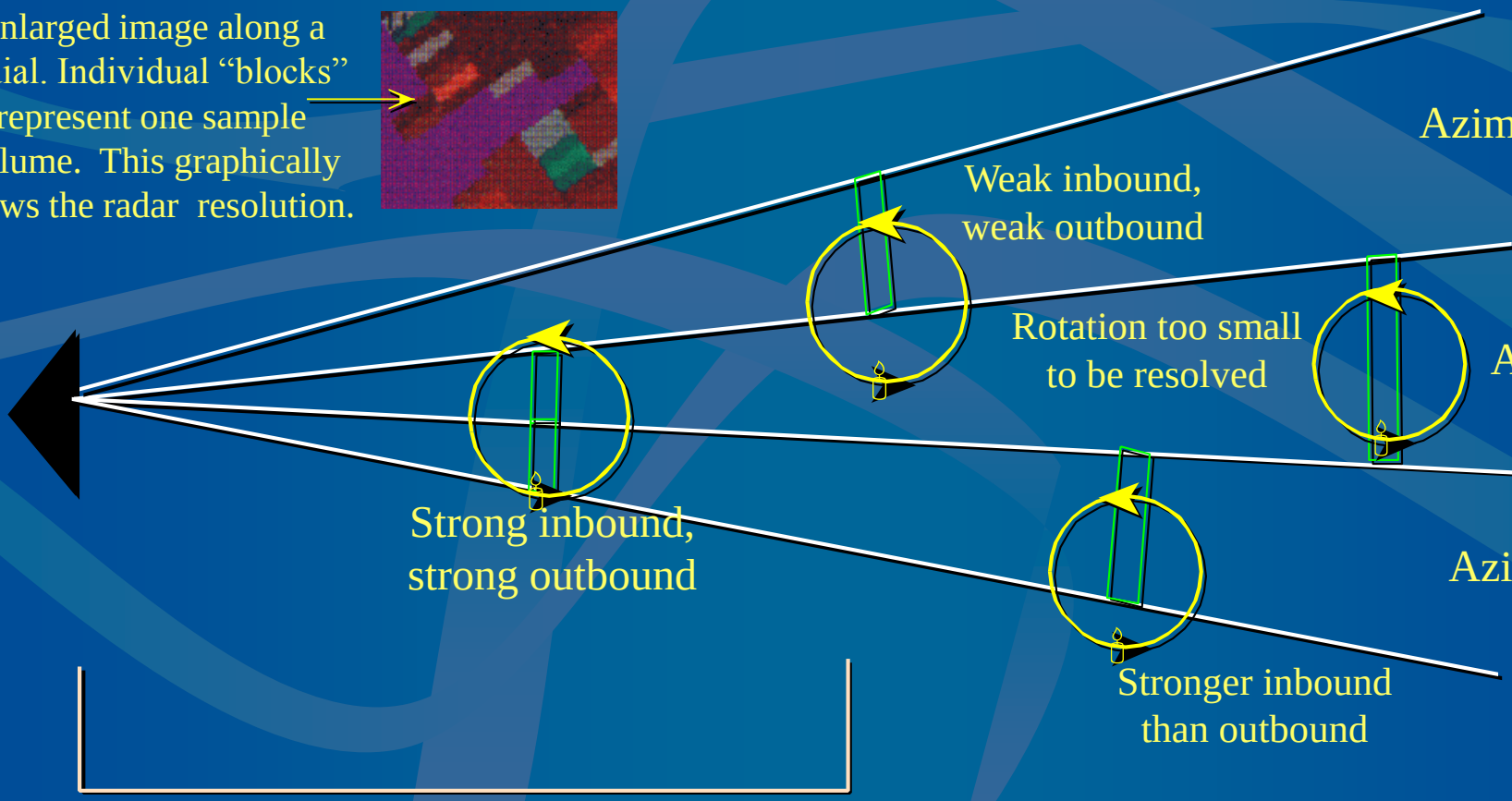
If R =	**60 NM**	**120 NM**	**180 NM**	**240 NM**
D =	**1 NM**	**2 NM**	**3 NM**	**4 NM**

Azimuth Resolution Considerations

Rotational couplet identification can be affected by azimuth resolution.

As the diagram shows, the closer a rotation is to the radar the more likely it will be identified correctly. If the rotation is smaller than the 1^0 beam width (possible at long ranges) then the rotation will be diluted or averaged by all the velocities in that sample volume. This may cause the couplet to go unidentified until it gets closer to the radar.

Enlarged image along a radial. Individual "blocks" represent one sample volume. This graphically shows the radar resolution.



Pulse Repetition Frequency- PRF

PRF controls the Max Radar Range and Max Unambiguous Velocities

PRF is the number of pulses per second transmitted by a radar

The Doppler Dilemma

R_{max} and V_{max} depend on PRF

R_{max} = The range to which a transmitted pulse can travel and return to the radar before the next pulse is transmitted.

V_{max} = The maximum mean radial velocity that the radar can unambiguously measure (before dealiasing).

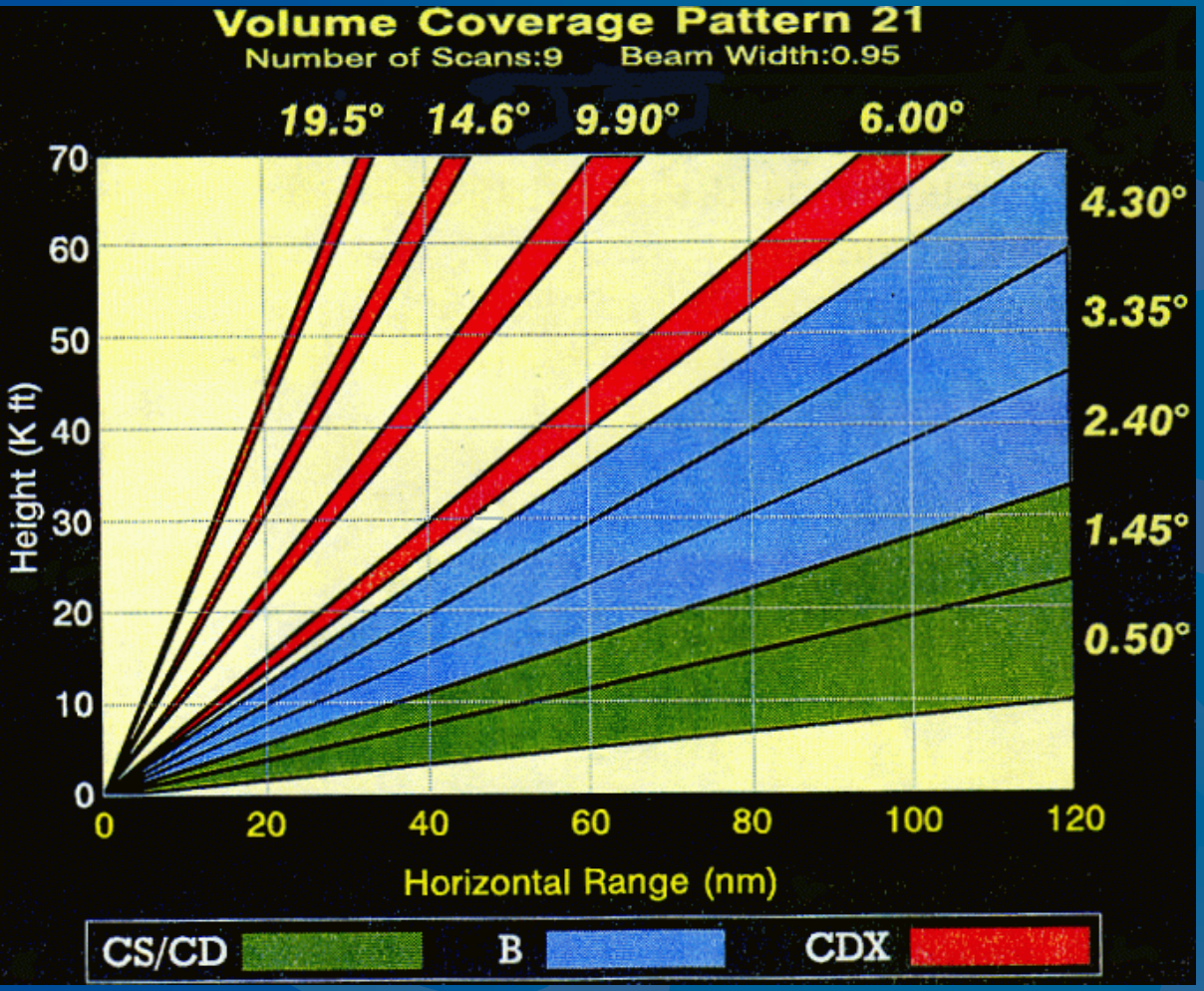
* R_{max} is inversely related to PRF
* V_{max} is directly related to PRF

As PRF increases, R_{max} decreases and V_{max} Increases!

The Doppler Dilemma: There is no single PRF that maximizes both R_{max} and V_{max}

Defeating the Doppler Dilemma

The WSR-88D employs a dual PRF scanning strategy to help defeat the "Doppler Dilemma"



The 88D performs redundant sampling on the lowest 2 elevation slices and interlaced sampling on the "middle" slices to maximize range/velocity data, and minimize ground clutter.

In this example of Volume Coverage Pattern (VCP) 21, the lowest two elevation slices are sampled twice. Once using a low PRF (CS) to maximize range data and then again using a high PRF (CD) to maximize velocity data. The middle slices (blue) are sampled once but use an alternating, or interlaced, high and low PRF (B) on each radial. The upper elevation slices use only a high PRF (CDX) to maximize velocity data. Range issues are not a problem in the higher elevations, precluding the use of a low PRF.

CS = Contiguous Surveillance

B = Batch

CD = Contiguous Doppler

CDX = Contiguous Doppler X

Volume Coverage Patterns of the 88-D

Precipitation Mode:

VCP 11 14 Slices*/5 minutes
VCP 21 9 Slices*/6 minutes

Clear Air Mode:

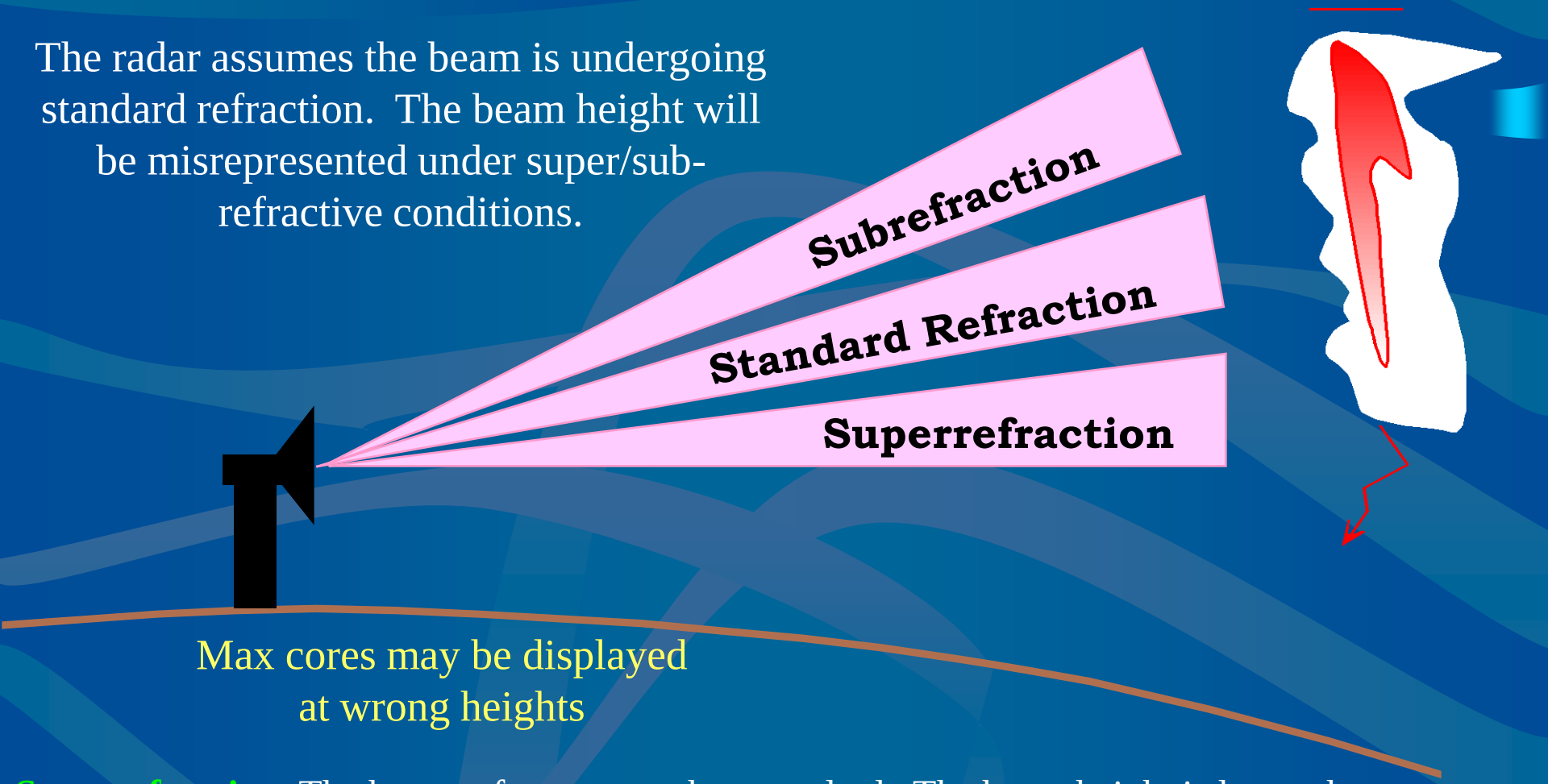
VCP 31 5 Slices*/10 minutes
(Long Pulse)

VCP 32 5 Slices*/10 minutes
(Short Pulse)

* Add 2 more slices to every VCP because the bottom two slices are sampled twice. See previous slide.

Atmospheric Refraction

The radar assumes the beam is undergoing standard refraction. The beam height will be misrepresented under super/sub-refractive conditions.



Max cores may be displayed at wrong heights

Superrefraction: The beam refracts more than standard. The beam height is lower than the radar indicates.

Subrefraction: The beam refracts less than standard. The beam height is higher than the radar indicates. Beam can overshoot developing storms.

Super/Sub Refraction

Super Refraction

This occurs when the beam propagates through a layer where :

- Temperature increases with height
- Moisture decreases sharply with height
  - * Radiation or subsidence inversion
  - * Warm, dry air advecting over cooler water surface
  - * Thunderstorm outflow

✓ Will likely produce ground clutter

Sub Refraction

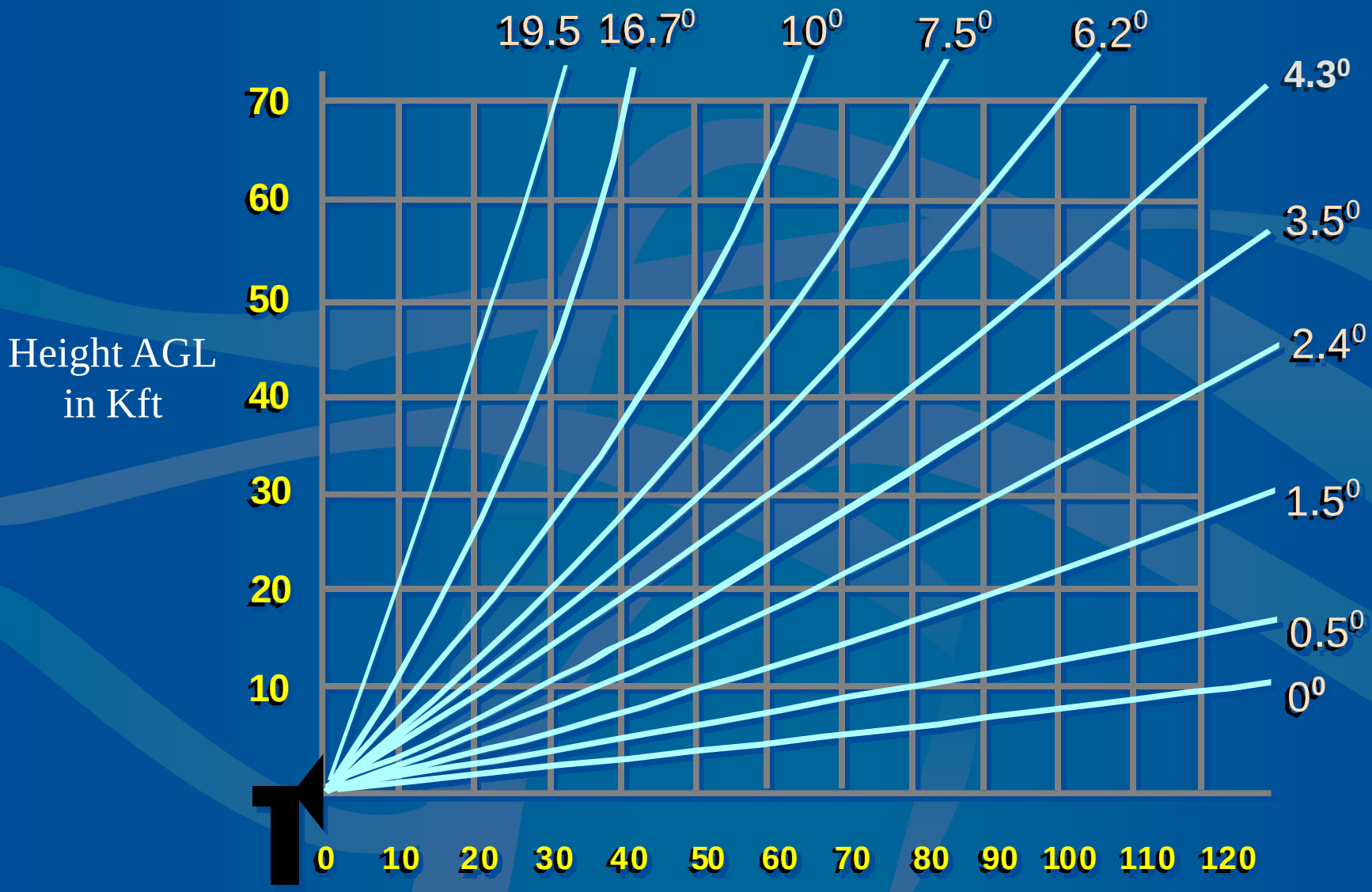
This occurs when the beam propagates through a layer where :

- Temperature lapse rate is ~ dry-adiabatic
- Moisture content increases with height
  - * Inverted V sounding (mid-afternoon, well mixed environment)

✓ Will help eliminate ground clutter

Beam Height vs. Range

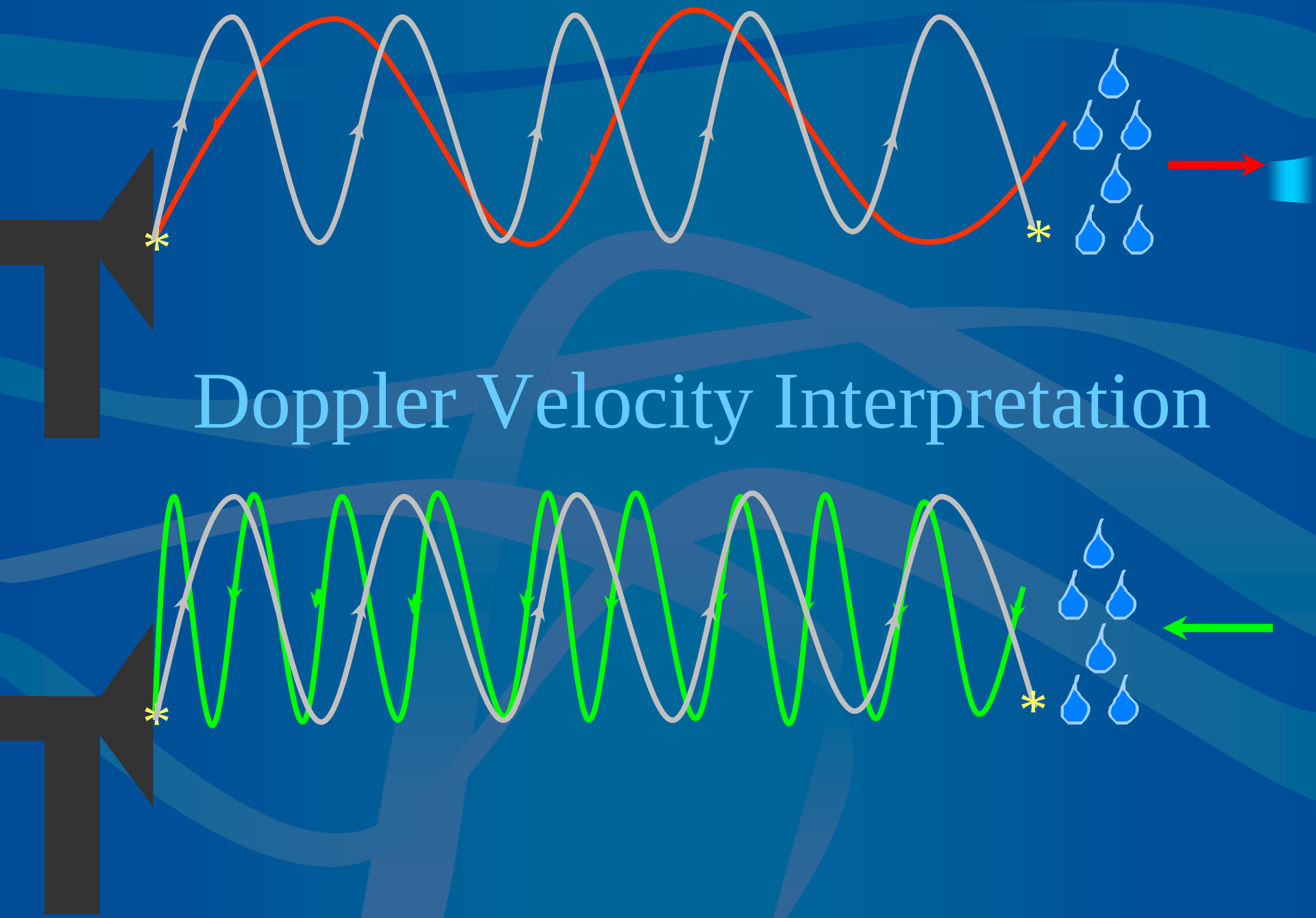
Standard Refraction Assumed



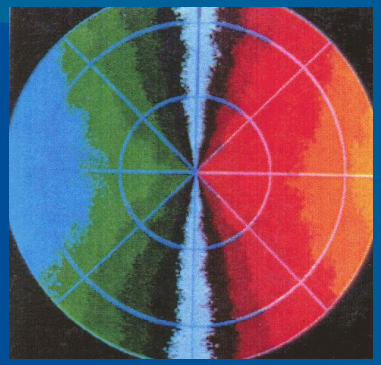
Odd Phenomena Seen on Radar

- Chaff- Look for it coming from the Military Operations Areas
- Migrating birds rising from nesting areas around sunrise and sunset
- Smoke from fires
- Sunrise/Sunset spike
- The unexplainable…

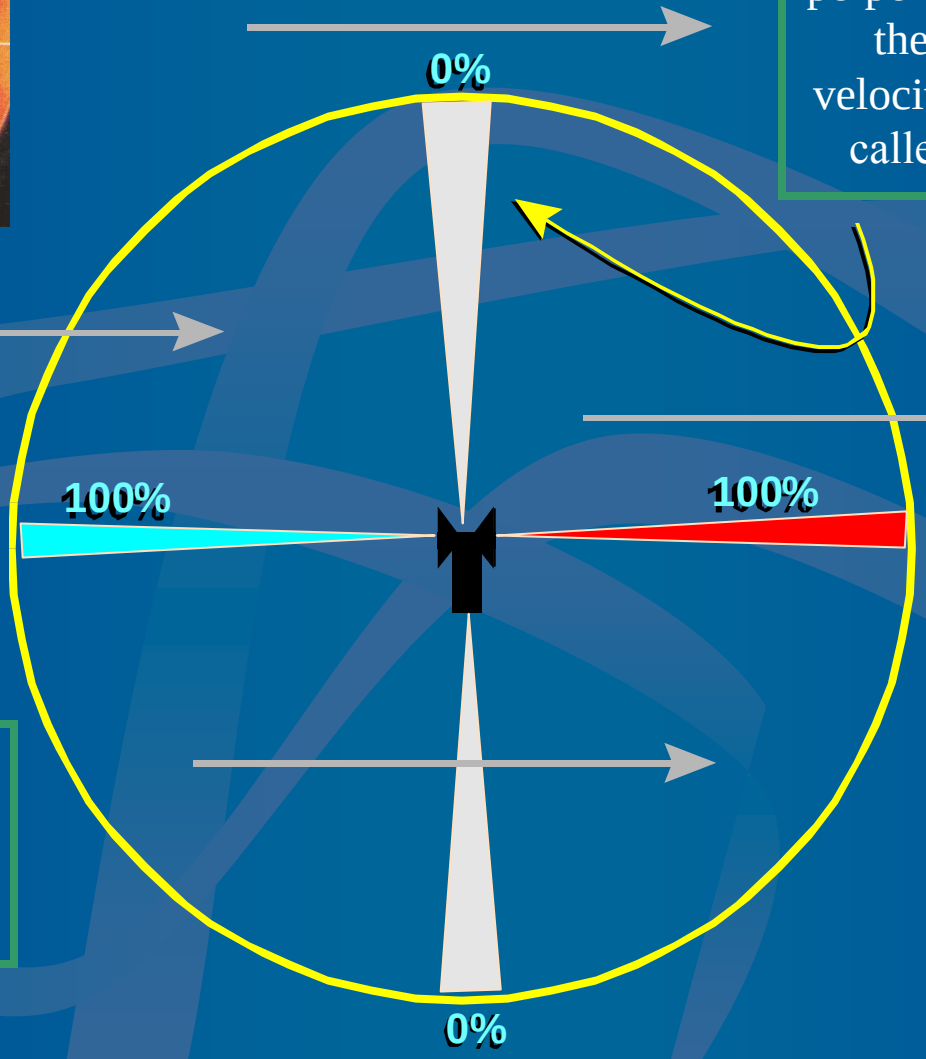
Doppler Velocity Interpretation



The Zero Isodop "Problem"



When the radial is perpendicular to the the wind, the radar displays zero velocity - This "zero zone" is called the "Zero Isodop".



When the wind velocity is parallel to the radial, the full component of the wind is measured

What percentage of actual wind will the radar detect?

0^0 = 100% - Parallel
15^0 = 97%
30^0 = 87%
45^0 = 71%
60^0 = 50%
75^0 = 26%
90^0 = 0% - Perpendicular

Large Scale Winds

Use the Zero Isodop to assess the vertical wind profile.

"S" Shape

"S" shape of the zero isodop indicates veering winds with height. Veering may imply warm air advection.

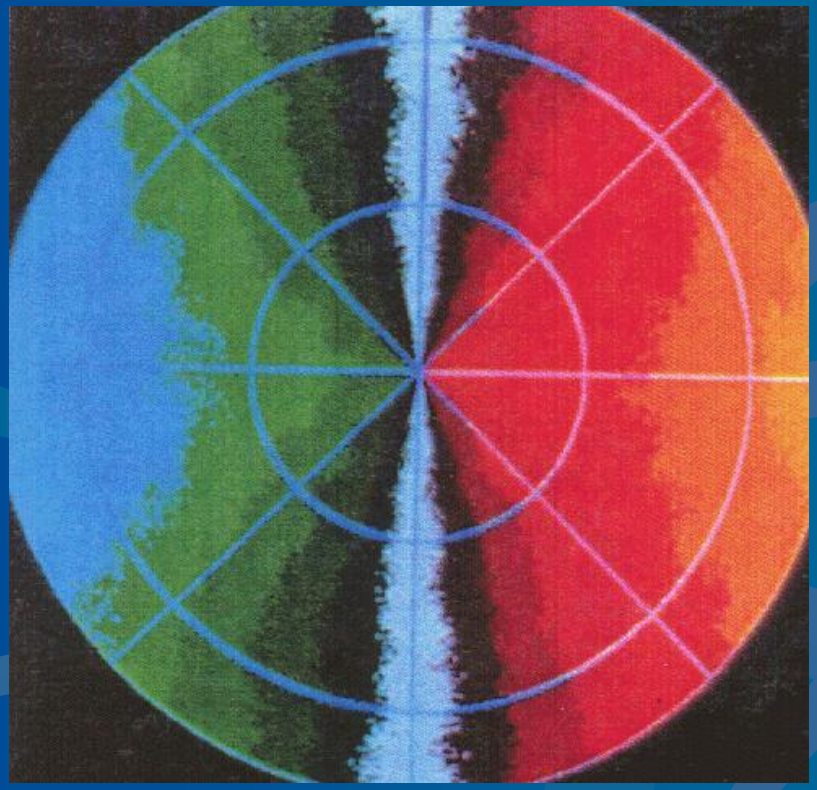
The combination shape of the zero isodop indicates both veering and backing winds with height.

Combination

Backward "S" Shape

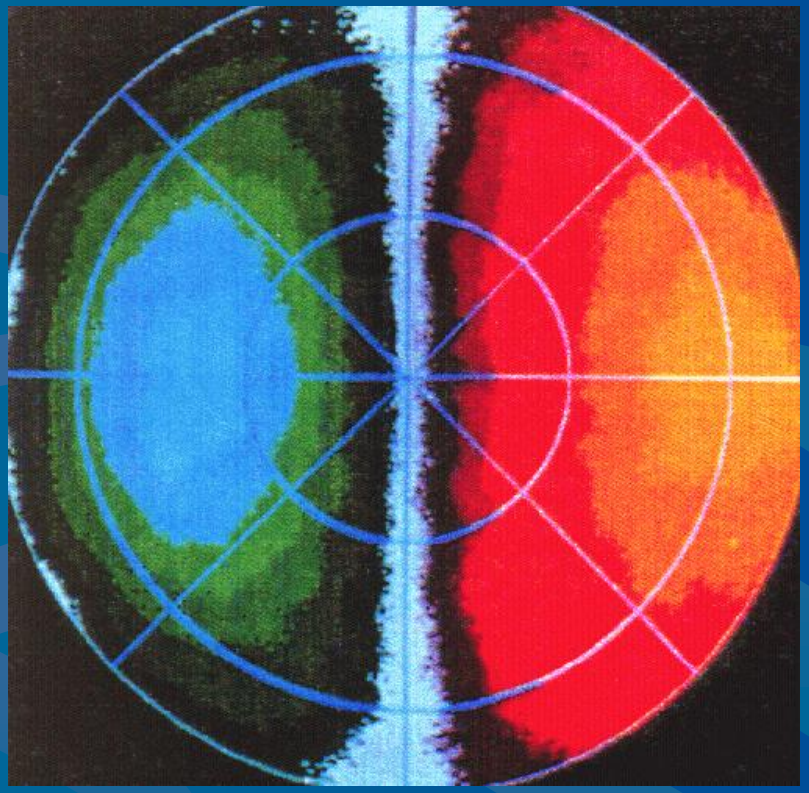
Backward "S" shape of the zero isodop indicates backing winds with height. Backing may imply cold air advection.

Large Scale Winds



Uniform Flow

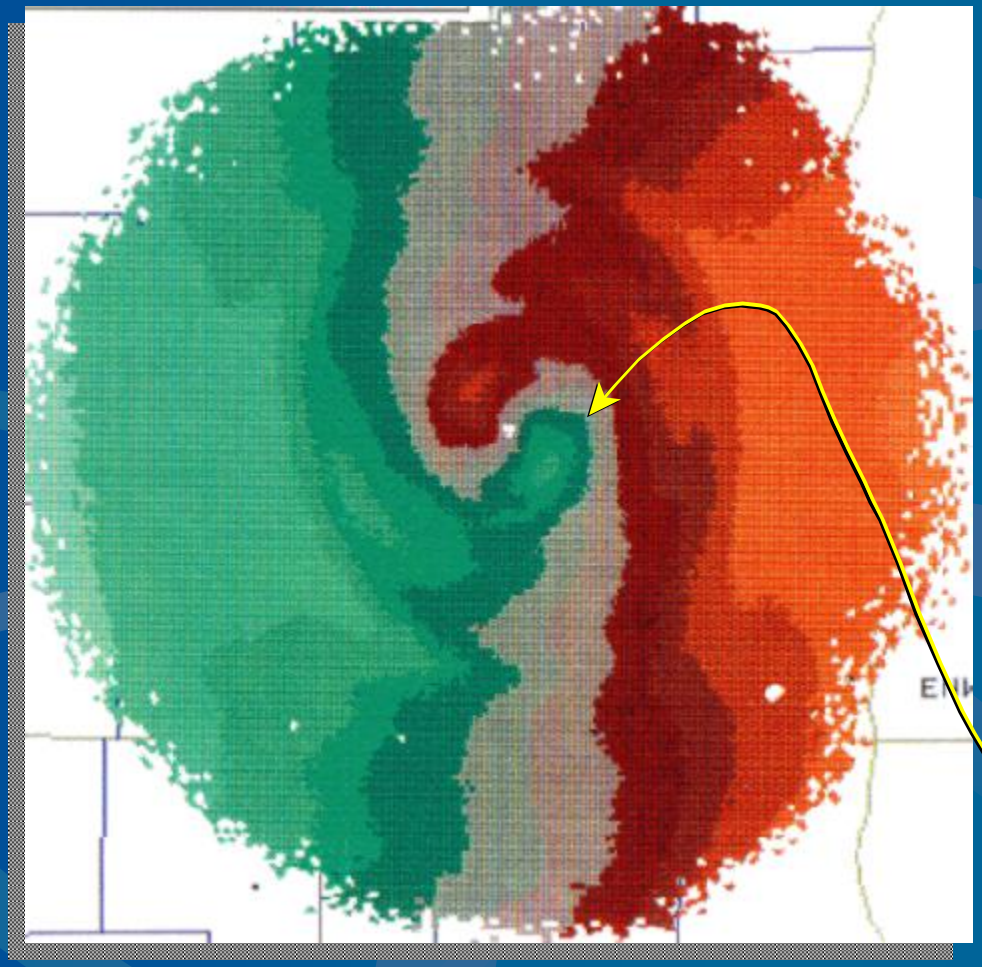
Straight Zero Isodop indicates uniform direction at all levels.

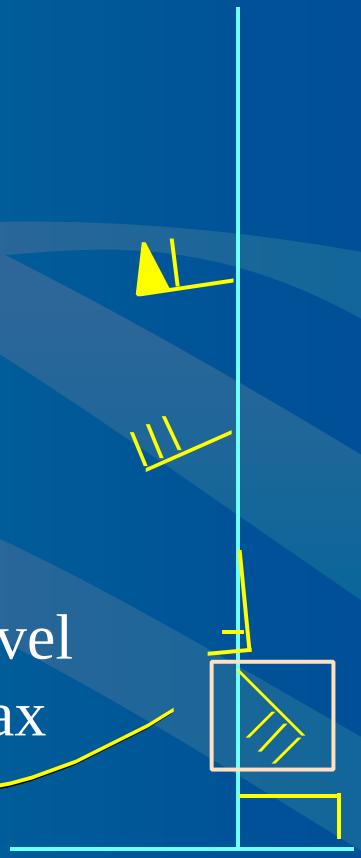


Uniform Flow with Jet Core

Straight Zero Isodop indicates uniform direction at all levels. The inbound/outbound max's show a jetcore aloft with weaker winds above and below.

Example from KMKX 88D

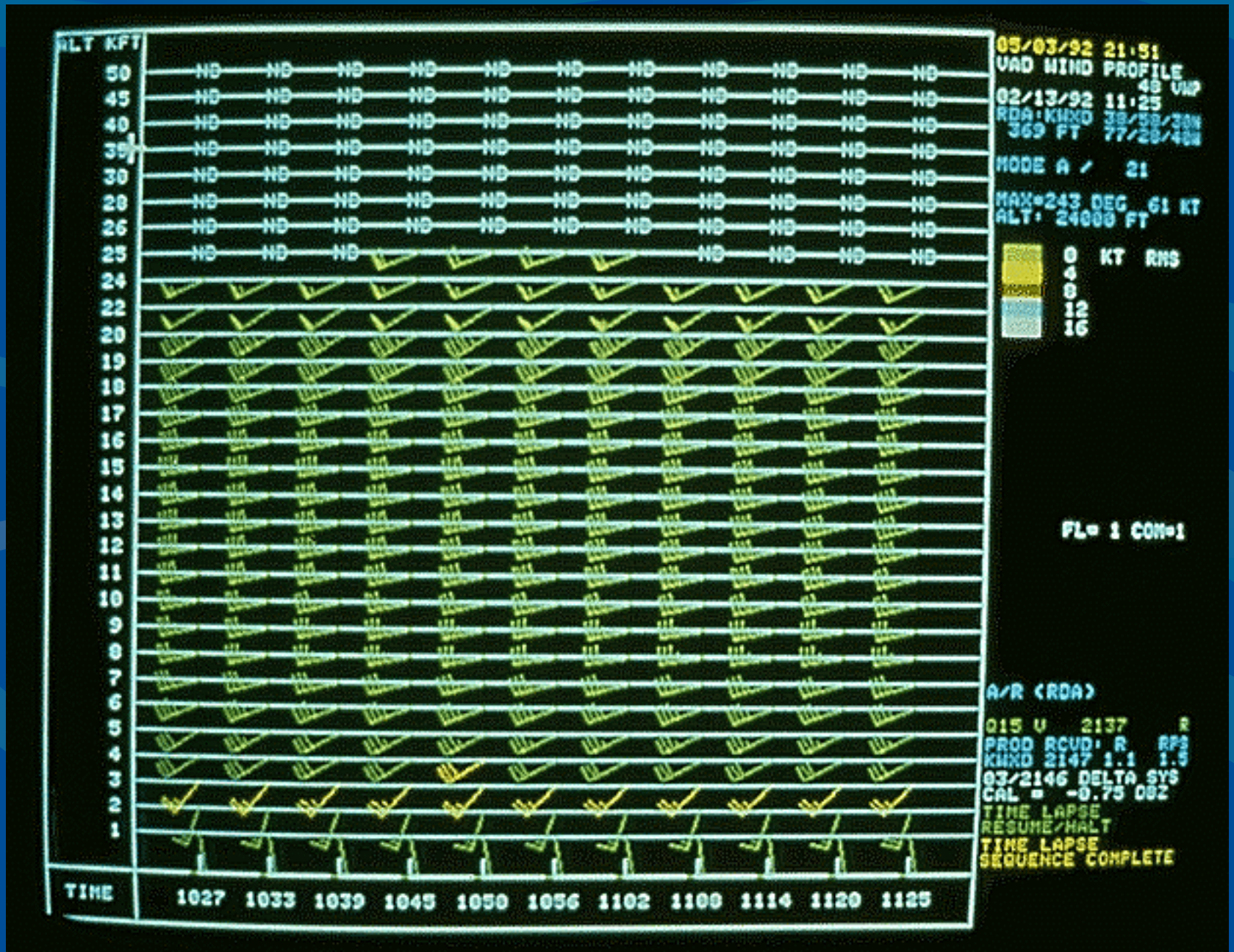




January 5, 1994

Steady snowfall

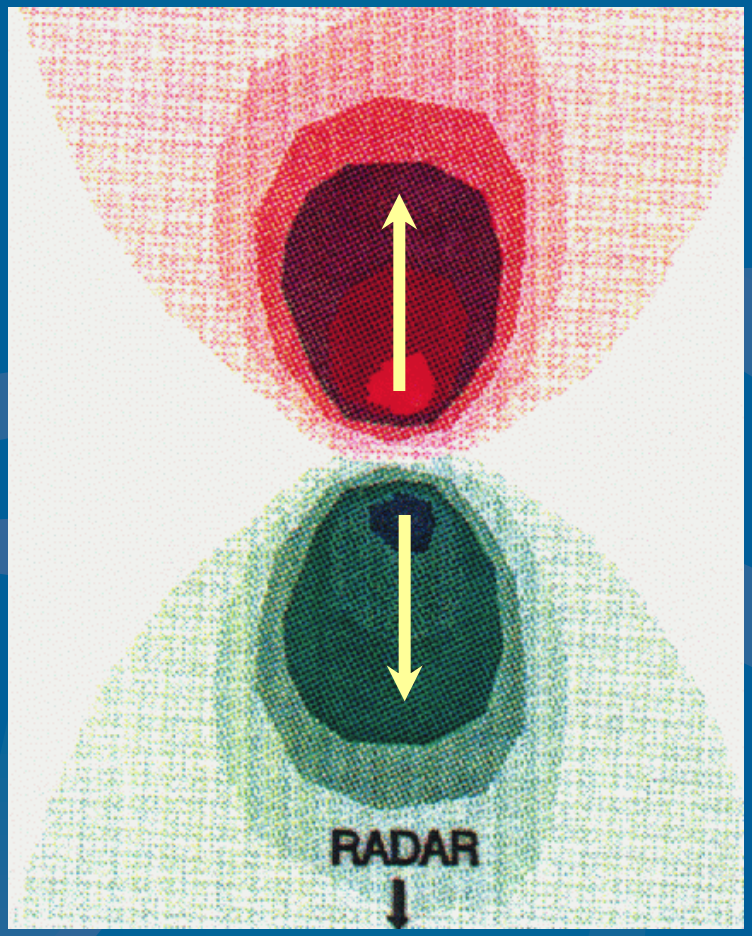
The VAD Wind Profile



Small Scale Winds

- Divergence/Convergence -

In all of the following slides, note the position of the radar relative to the velocity signatures. This is critical for proper interpretation of the small scale velocity data.

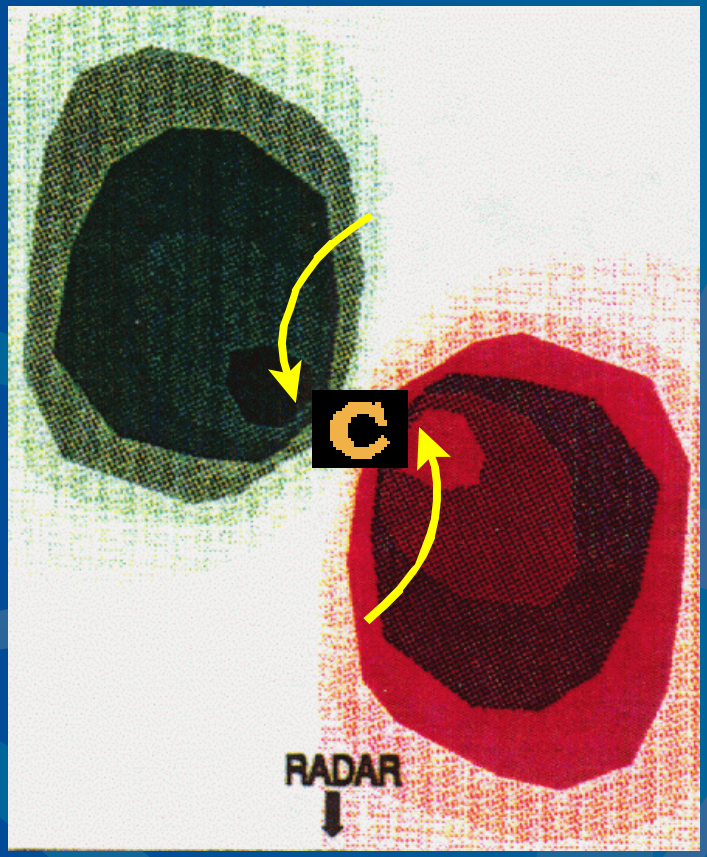


Divergent Signature
Often seen at storm top level or near the ground at close range to a pulse type storm

Convergence would show colors reversed

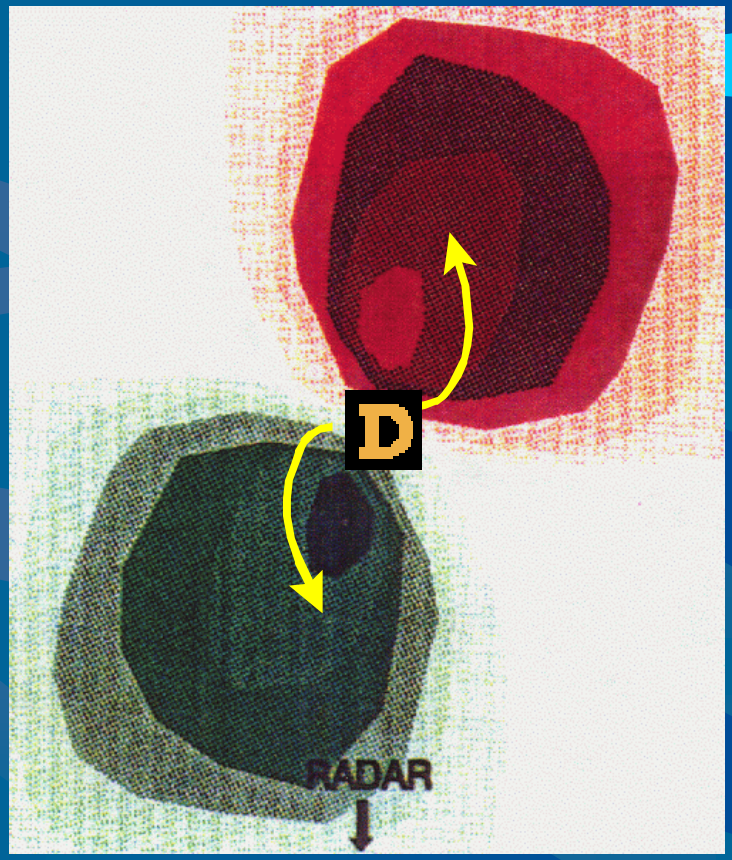
Small Scale Winds

- Cyclonic Convergence/Divergence -



Cyclonic Convergence

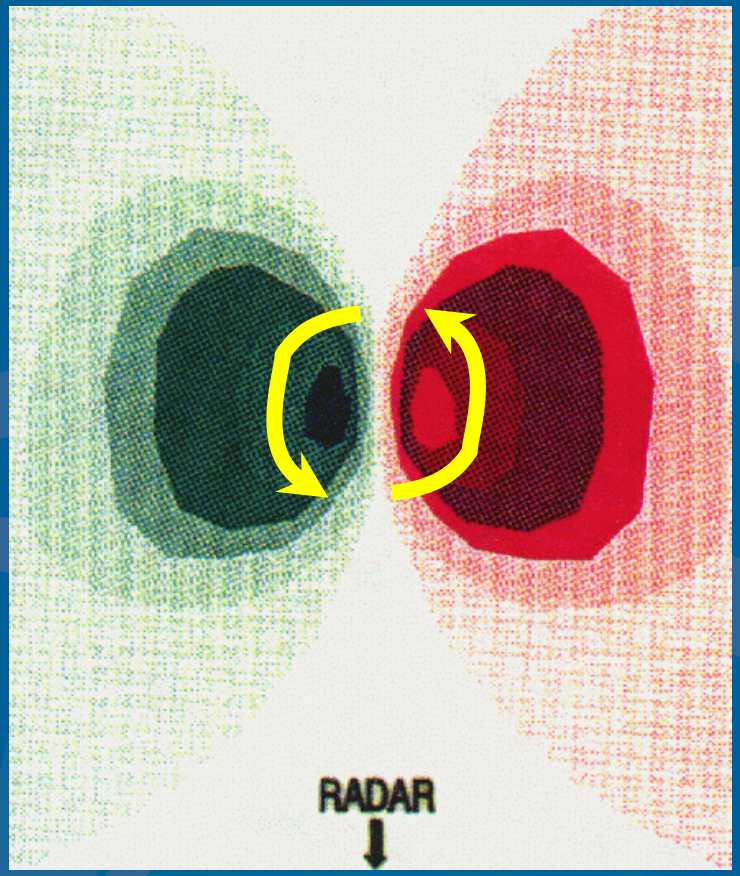
Anticyclonic convergence/ divergence would show colors reversed in each panel.



Cyclonic Divergence

Small Scale Winds

- Pure Cyclonic Rotation -

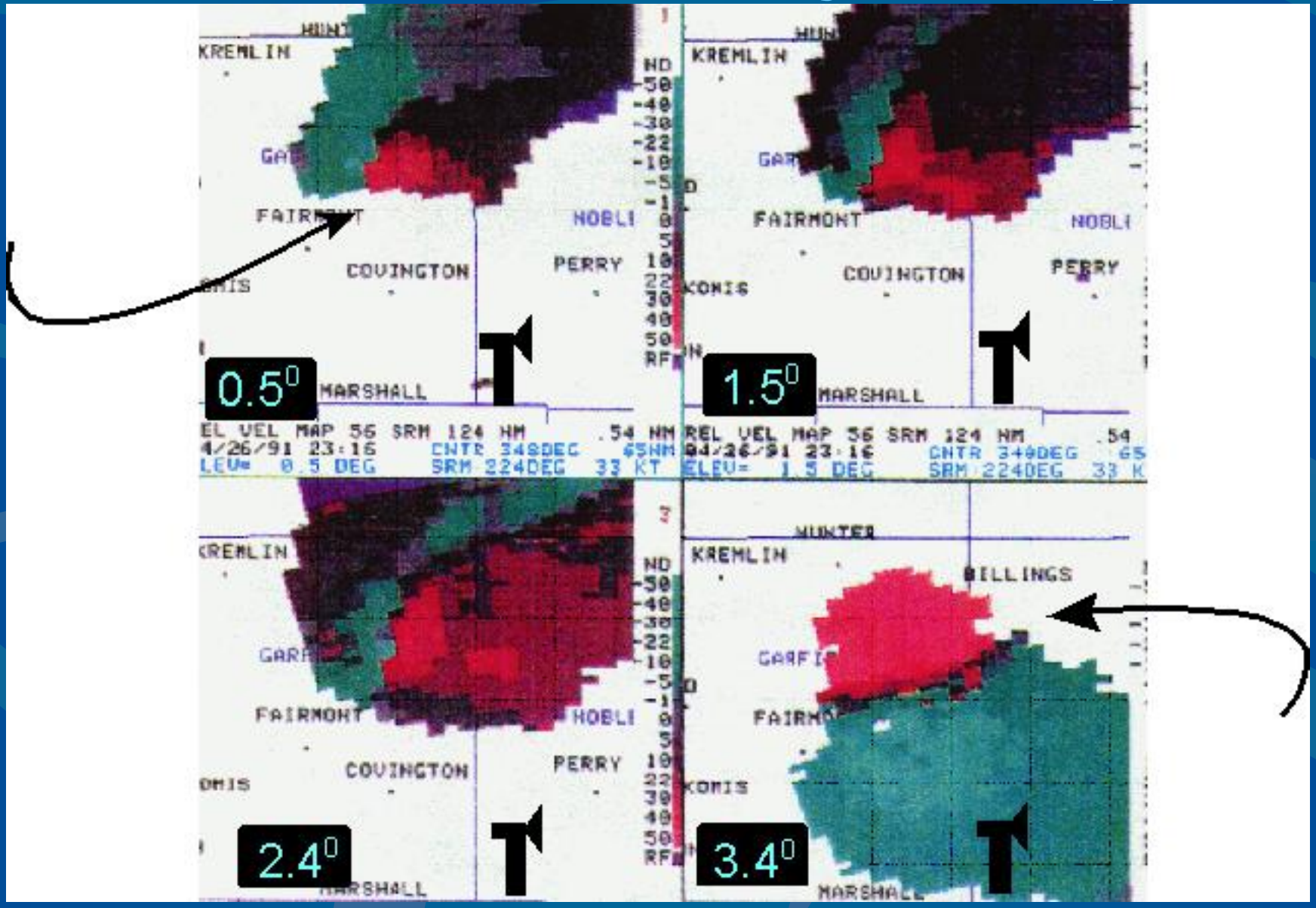


Pure Cyclonic Rotation

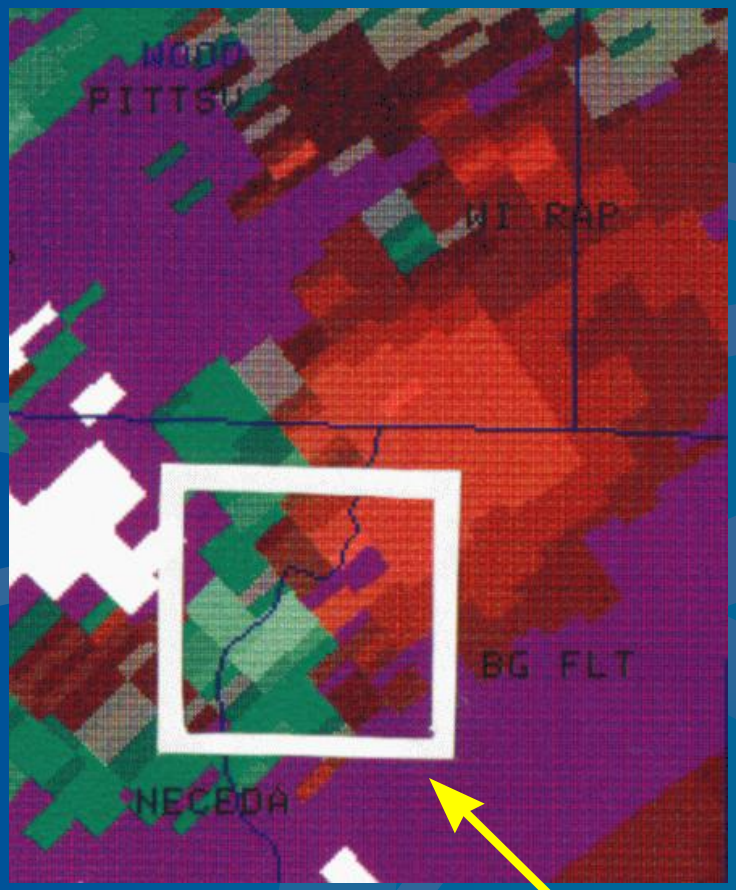
Anticyclonic rotation would show colors reversed

Example

Small Scale Velocity Example



Small Scale Velocity Example



Rotation seen with the
Big Flats Tornado.
August 27, 1994 ~ 9 PM.

Storm Relative Velocity - SRV
vs.
Base Velocity

In General:

When diagnosing rotational characteristics, use SRV

- SRV subtracts out the motion of a storm to display pure rotational characteristics of that storm. Often, the motion of the storm will mask or "dilute" the rotational information. This is especially true when rotations are subtle.

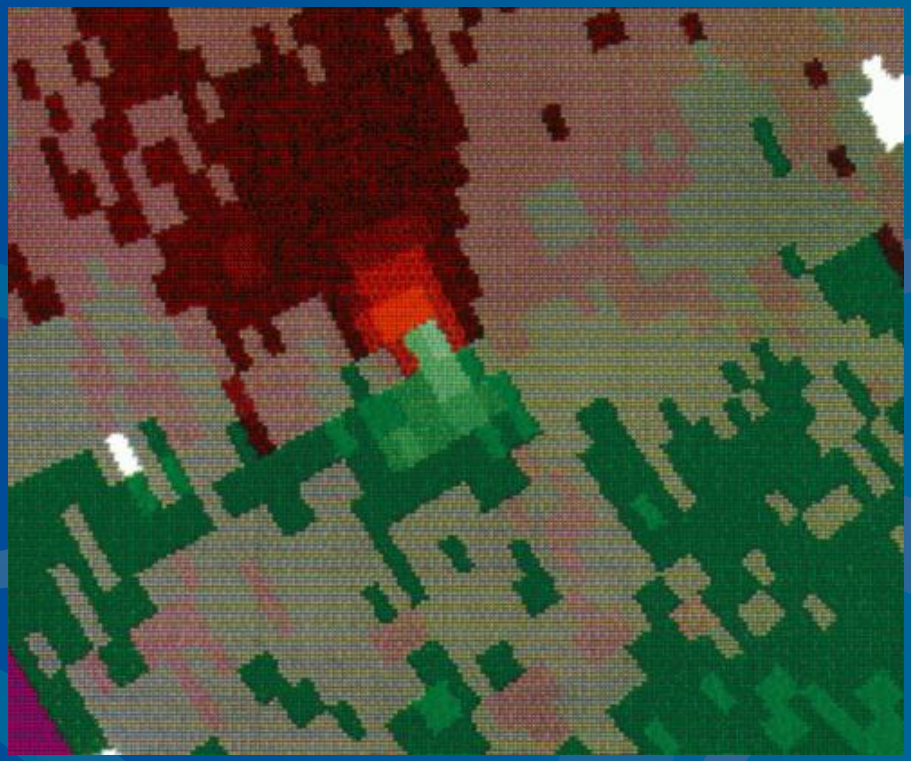
When diagnosing Straight Line Winds (bow echo, derecho, microbursts), use Base Velocity

- The strength of an advancing line of storms producing straight line winds is a sum of the winds produced by the storms, plus the movement of the storms. Using SRV would take one component away.

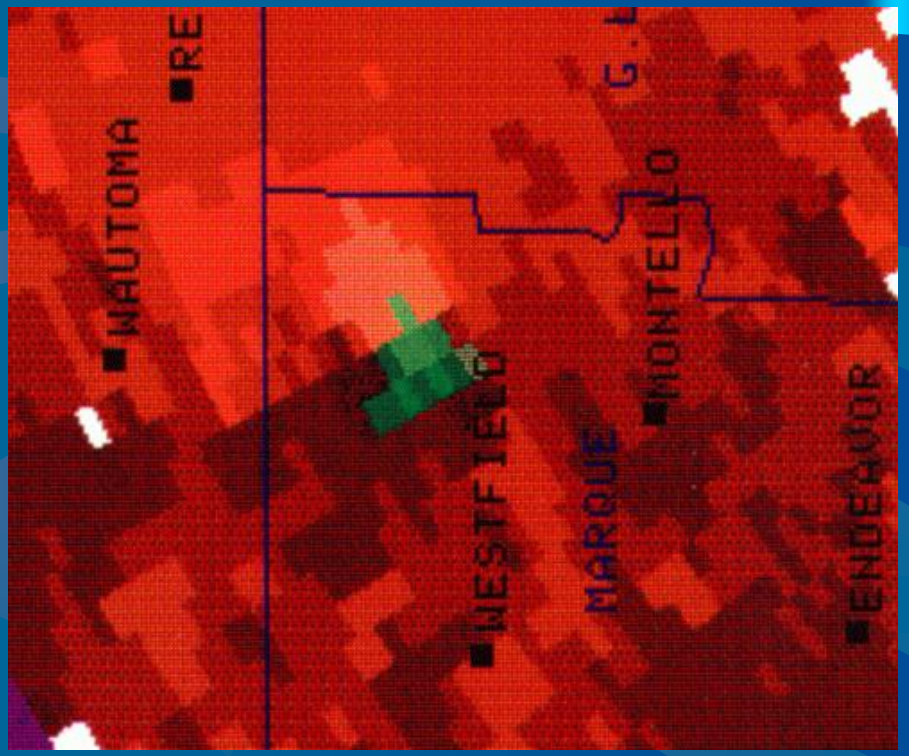
Examples →

SRV vs. Base Velocity

- Strong Rotation -



Base Velocity

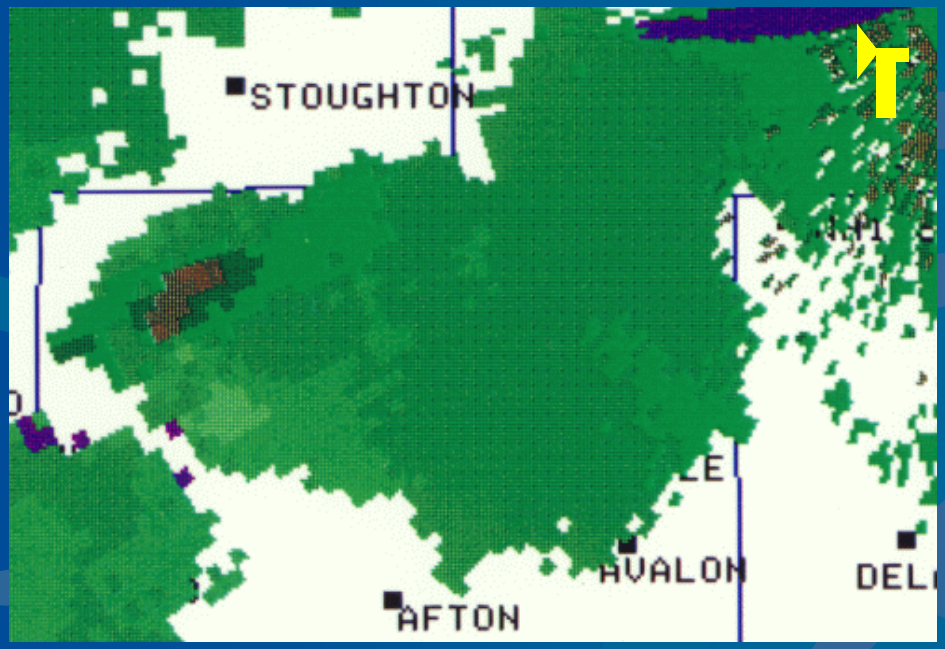


Storm Relative Velocity

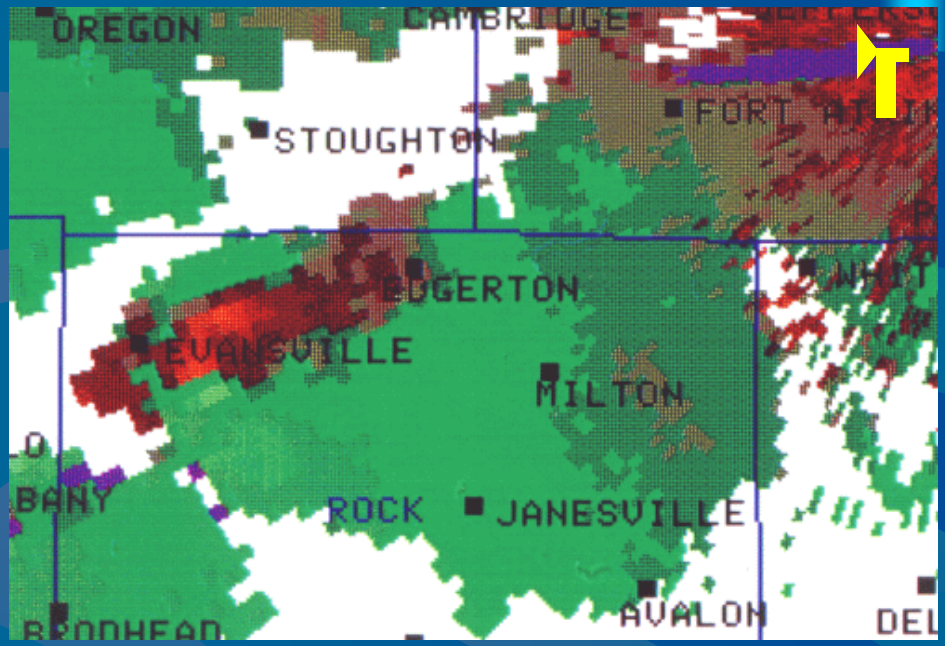
Persistent rotation from Big Flats Storm

SRV vs Base Velocity

- Subtle Rotation -



Base Velocity



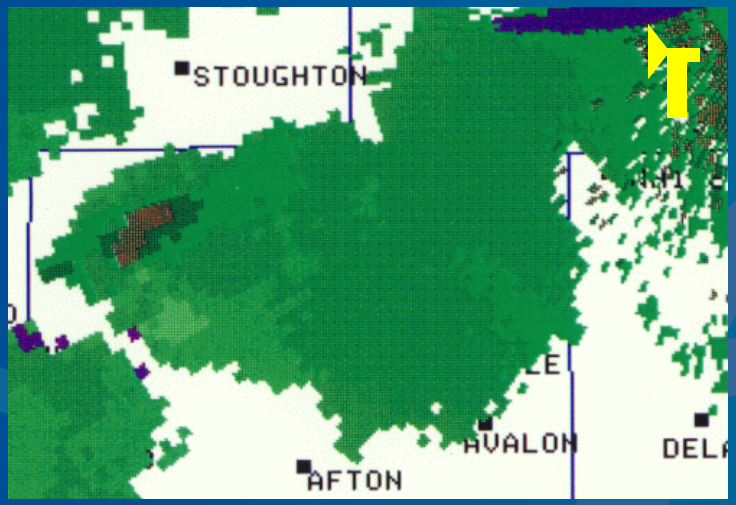
Storm Relative Velocity

Janesville F2 tornado. June 25th, 1998 ~ 700 PM

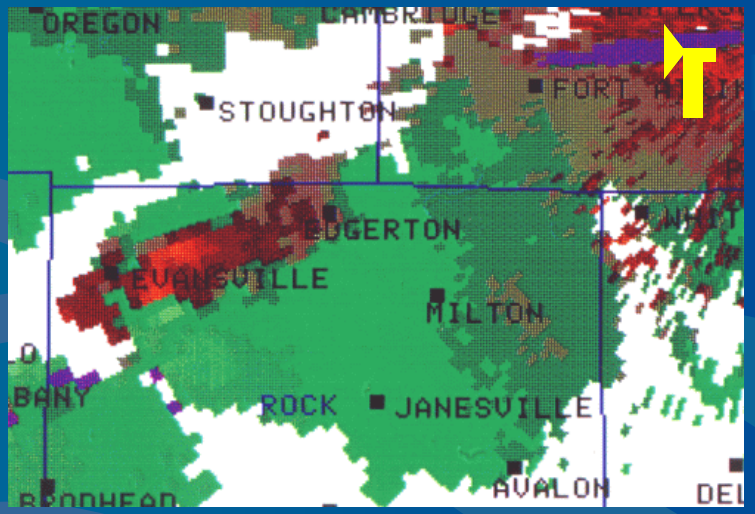
Interesting note: These scans are at 3.4^0 elevation. The 0.5^0 elevation showed little rotational information.

SRV vs Base Velocity

- Subtle Rotation -



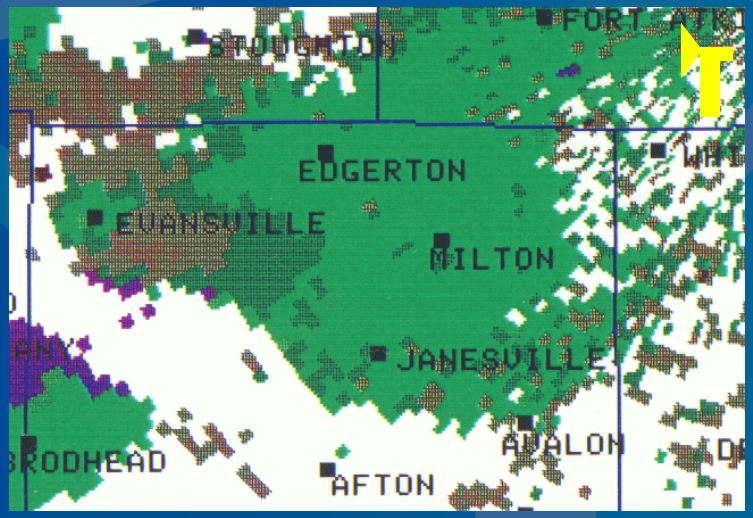
3.4^0



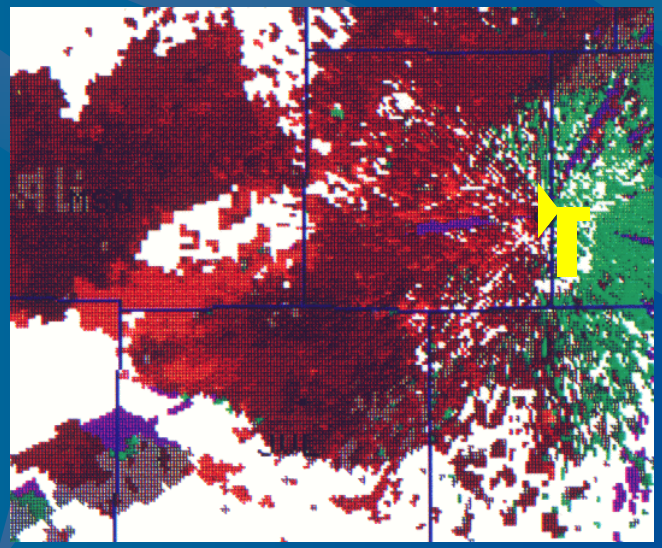
Base Velocity

Little/no rotation seen at lowest elevation

Storm Relative

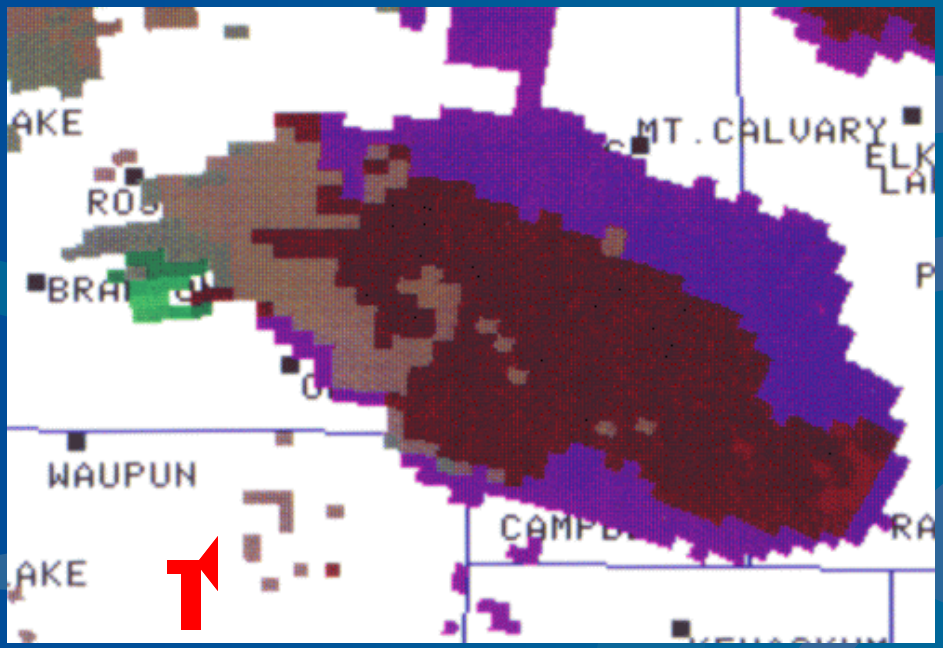


0.5^0

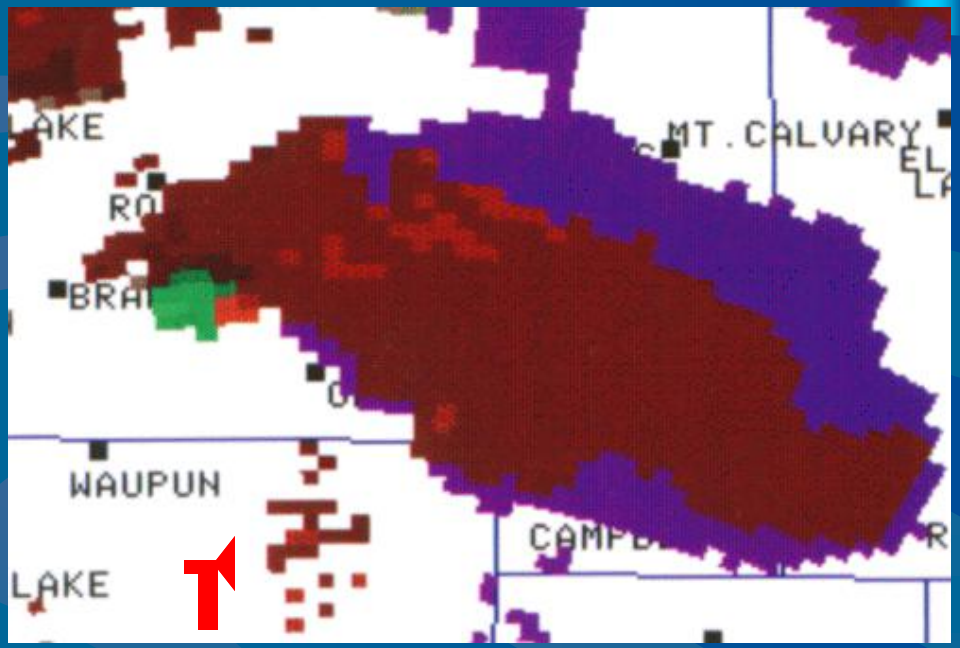


SRV vs Base Velocity

- Oakfield -



Base Velocity

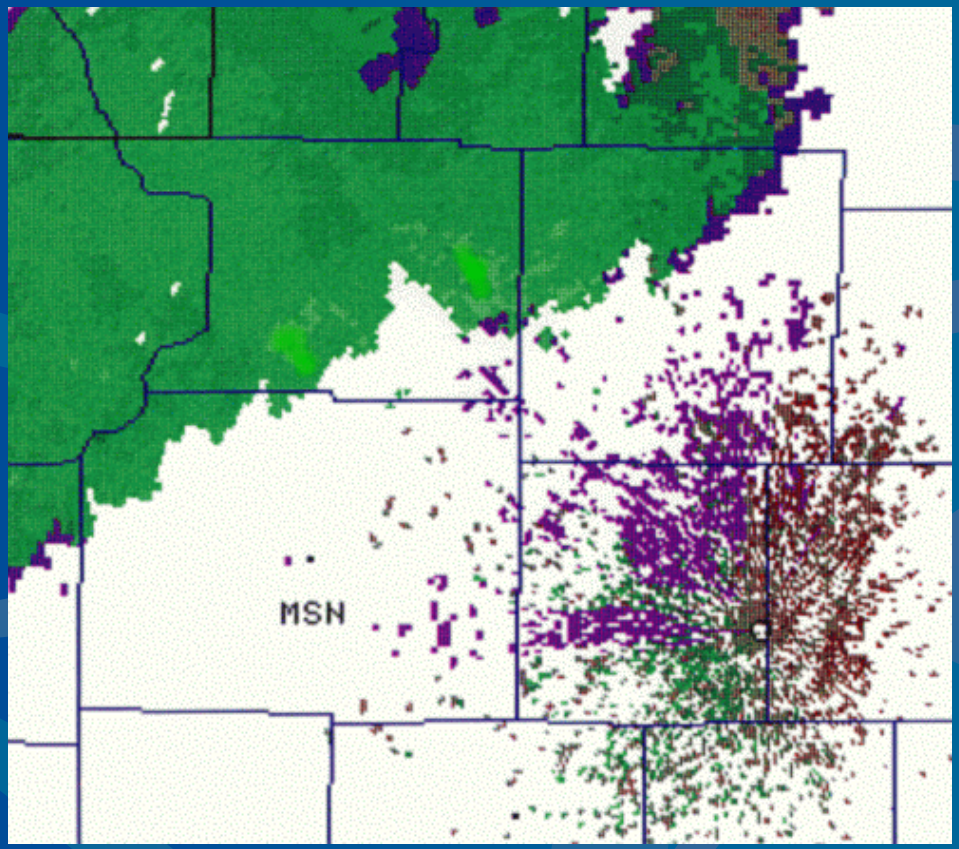


Storm Relative Velocity

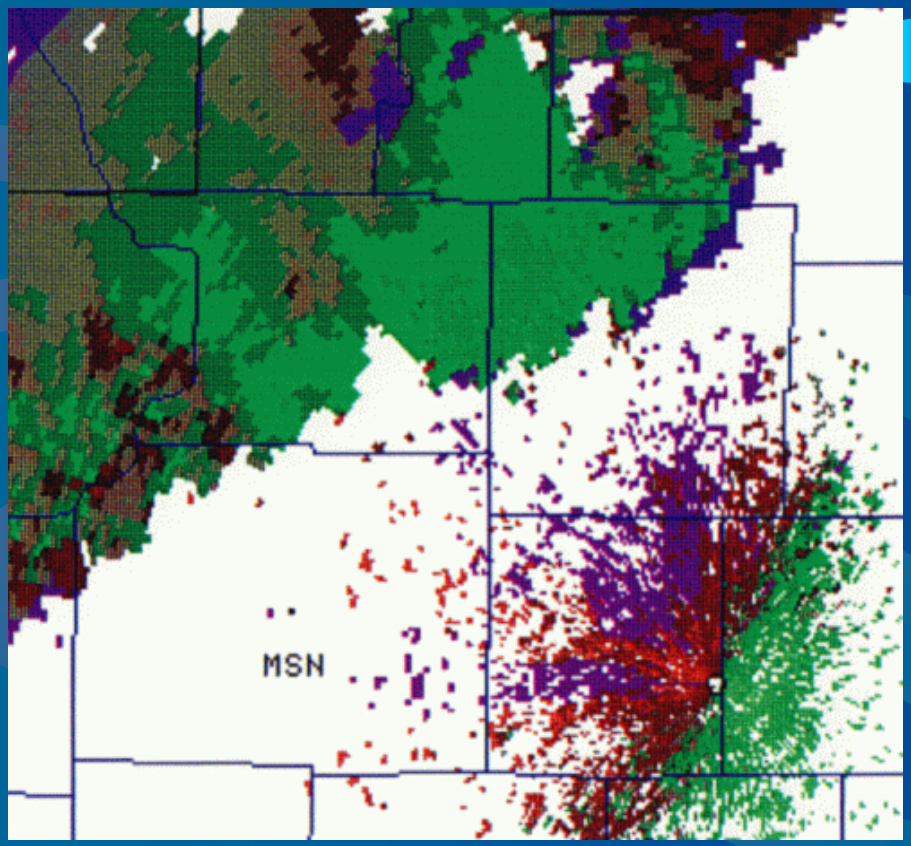
Oakfield F5 tornado. July 18, 1996. Although the rotation was intense, the low precip (LP) nature of the storm at this time, limited the amount of energy returned back to the 88D by precipitation targets. In this case, though the rotation was strong, the SRV clearly was the better tool for diagnosing the strength of the rotation.

SRV vs Base Velocity

- Straight Line Winds -



Base velocity shows max inbound winds of 55 to 60 kts.



SRV shows max inbound winds of 30 to 40 kts.

Pre-Storm Environment

The three main elements to assess are:

Moisture, Stability and Lift

Dewpoints/Precipitable Water

LI’s

CAPE

Jet Position (coupling?)

Cap Strength/CIN

Boundaries

Wet Bulb Zero

BRN

Helicity

Energy Helicity Index -EHI

LI's and Moisture

LI's

LI = -3 to -6 Moderately Unstable

LI = -6 to -9 Very Unstable

LI = < -9 Extremely Unstable*

* LI's even lower are increasingly likely to exist under a capped environment

Best to use the most unstable parcel in a layer up to about 850 mb. A surfaced based LI may be unrepresentative if boundry layer is under a shallow inversion.

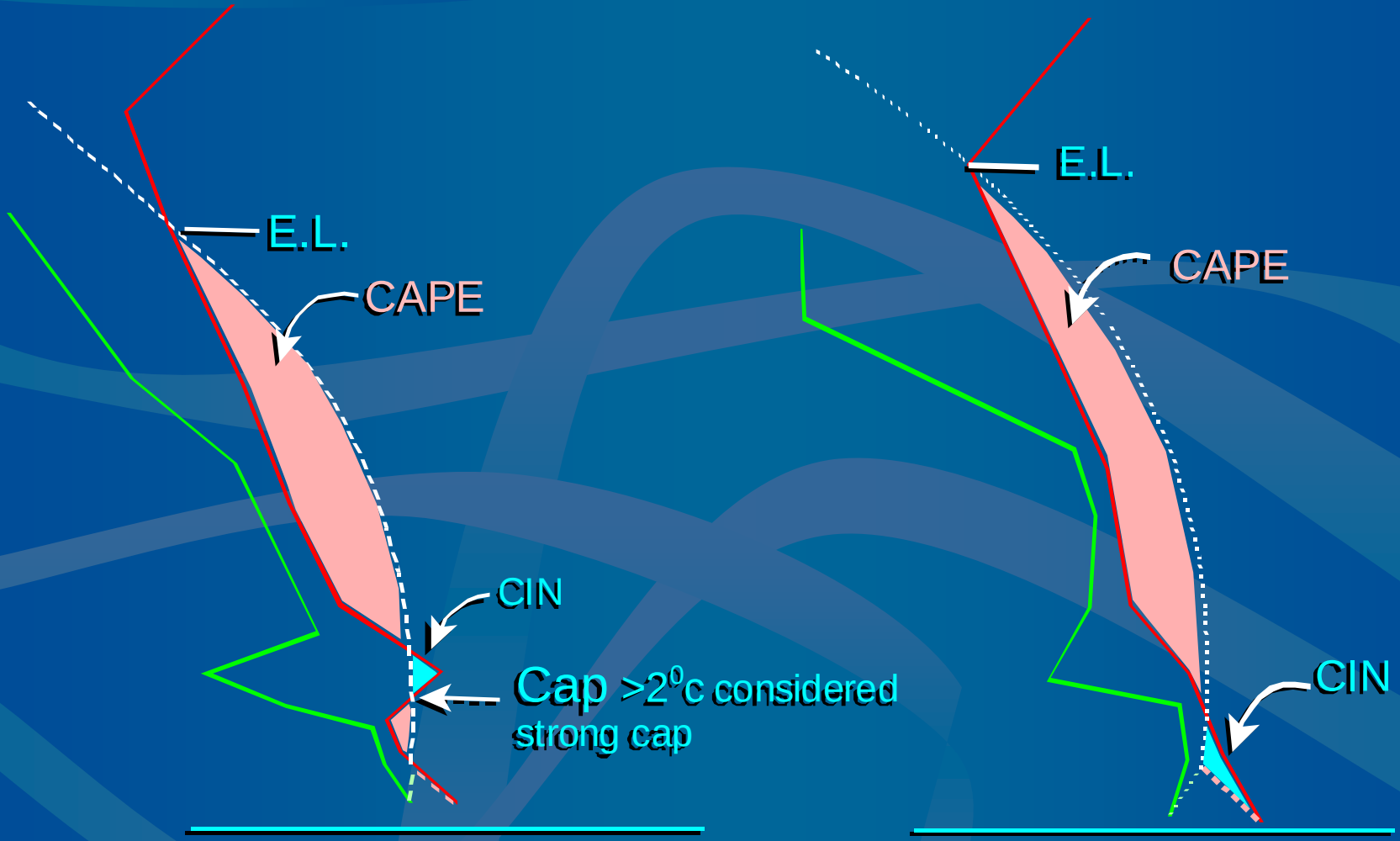
Moisture

Surface - 600 F dewpoint or higher

850 mb - 120 C dewpoint or higher

1000-500mb Precipitable water - 1.5" or higher

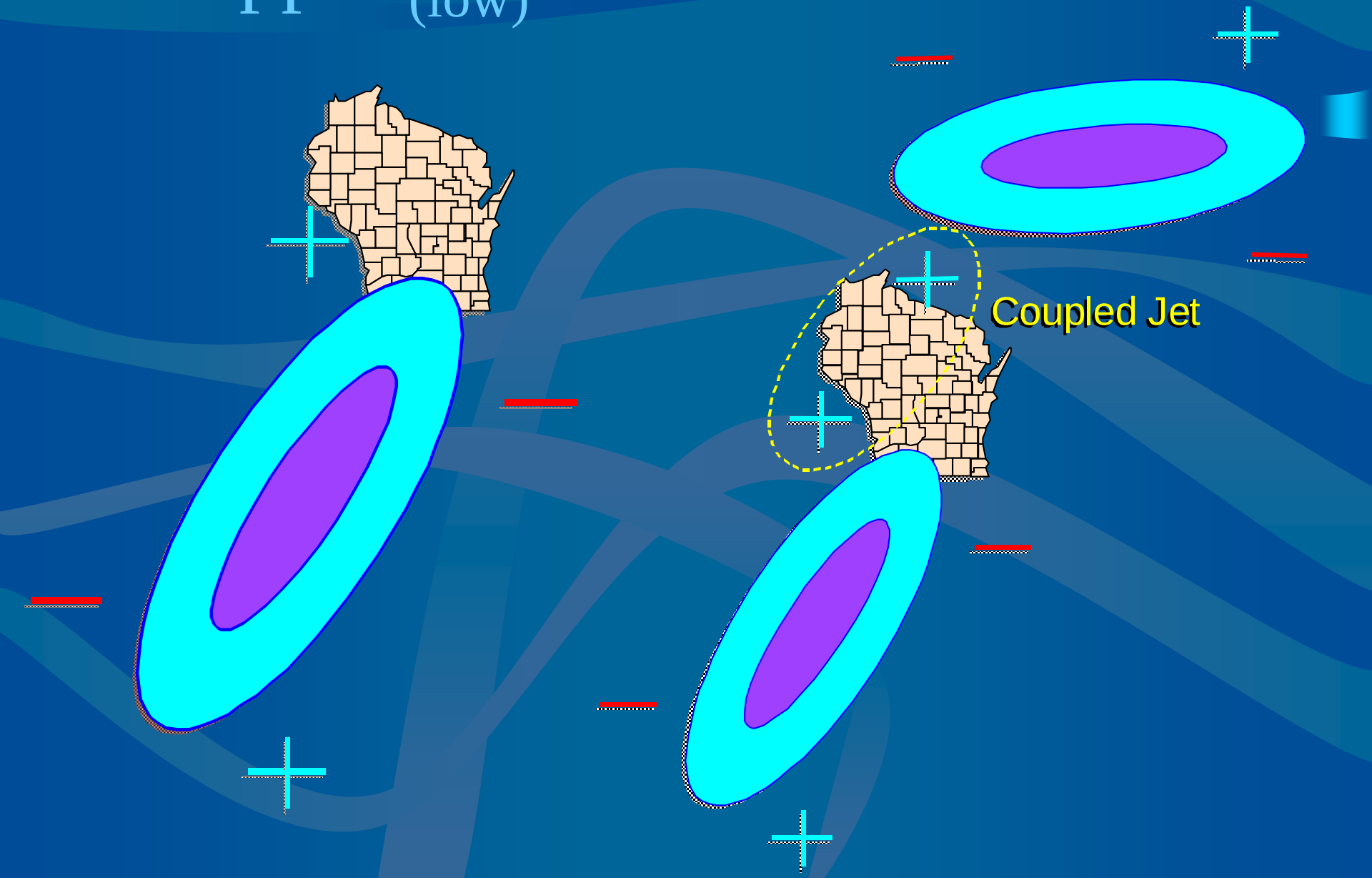
CAPE \ CIN and Cap



700 mb +100 C used as edge of cap

The edge of a cap is often a good place to watch for “Back-Building”, nearly stationary, flood producing storms. This is especially true if there is a focusing, trigger mechanism available.

Upper (low) Level Jet Influence



Shear and Thermal Instablility

The most severe, organized storms occur in environments where the shear and thermal instability are both moderate or strong and well balanced.

Supercells seem to be the favored mode of convection when the low-level, storm relative winds are greater than 19 knots and veer by roughly 90^0 in the lowest 4 km.

Bulk Richardson's Number

The BRN usually is a good overall indicator of convective storm type within given environments. It incorporates buoyant energy (CAPE) and the vertical shear of the horizontal wind, both of which are critical factors in determining storm development, evolution, and organization.

BRN < 10 Strong vertical wind shear and weak CAPE. The shear may be too strong given the weak buoyancy to develop sustained convective updrafts. However, given strong enough forcing, rotating supercells could evolve.

(I1, M1)

BRN = 10 to 45 "Sweet Spot" Associated with supercell development.

(M3,P3,H3)

BRN > 50 Relatively weak vertical wind shear and high CAPE which suggests pulse/multicellular storm development is most likely.

(N3,K3,B2)

S-R Helicity and EHI

Storm-relative helicity is an estimate of a thunderstorm's potential to acquire a rotating updraft given an environmental vertical wind shear profile. It integrates the effects of S-R winds and the horizontal vorticity (generated by vertical shear of the horizontal wind) within the inflow layer of a storm.

Hs-r = 150	The approximate threshold for supercell development
Hs-r = 150 to 299	Weak tornadoes (F0 and F1) possible
Hs-r = 300 to 449	Strong tornadoes (F2 and F3) possible
Hs-r > 450	Violent tornadoes (F4 and F5) possible

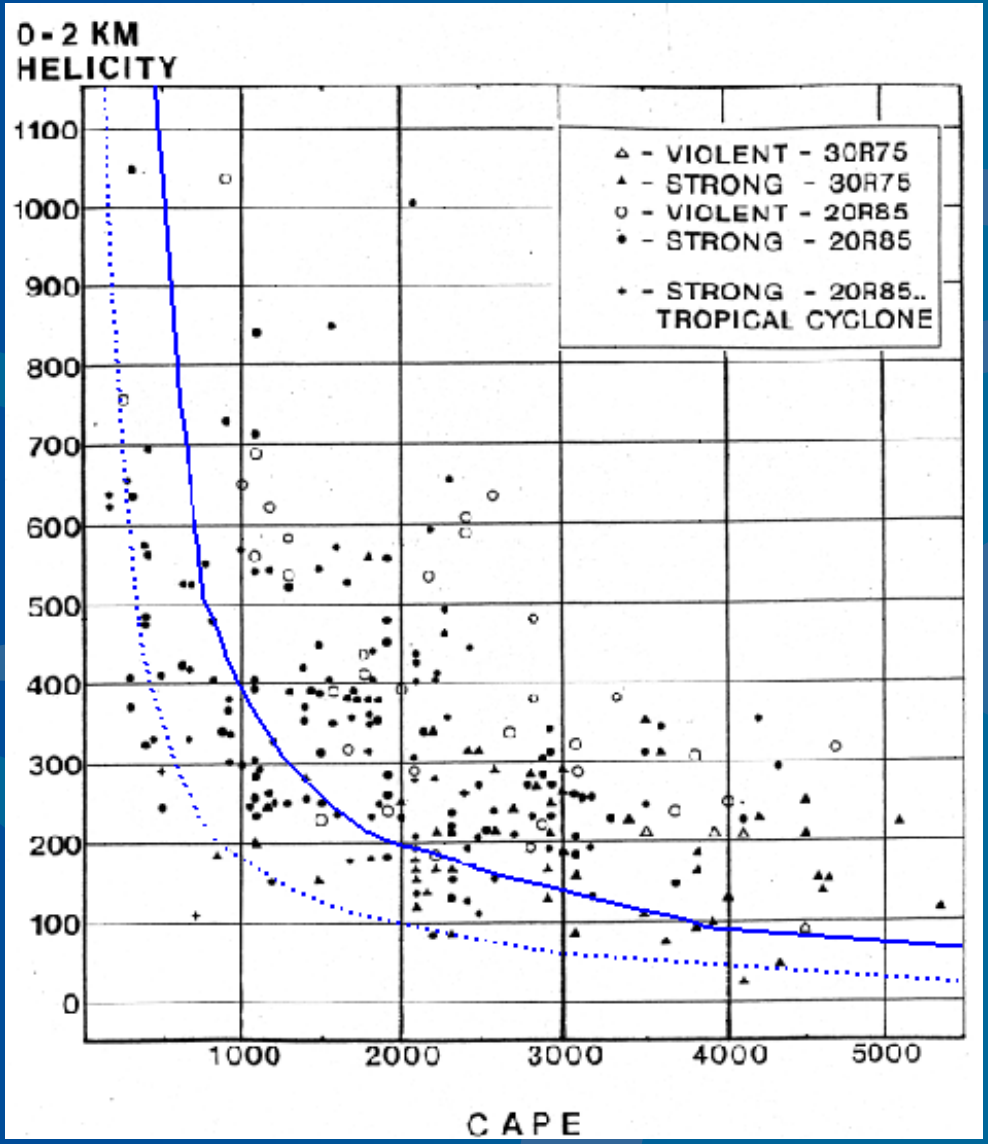
An intense rotating updraft can form with relatively weak CAPE if the vertical wind shear and storm-relative inflow are strong. Relatively low S-R helicity usually can be compensated by high instability to produce a rotating updraft. The EHI attempts to combine CAPE and S-R helicity into one index to assess the potential for supercell and mesocyclone development. High EHI values represent an environment possessing high CAPE and/or high S-R helicity.

EHI < 1.0	Supercells and tornadoes unlikely in most cases
EHI = 1 to 2	Supercells and tornadoes are possible but generally tornadoes are not of violent or long lived nature
EHI = 2 to 2.4	Supercells more likely and mesocyclone-induced tornadoes possible.
EHI = 2.5 to 2.9	Mesocyclone-induced supercellular tornadoes more likely.
EHI = 3.0 to 3.9	Strong mesocyclone-induced tornadoes (F2/F3) possible.
EHI > 4.0	Violent mesocyclone-induced tornadoes (F4/F5) possible.

H+12 ETA model produced an EHI of 5.5 over Oakfield area on July 18, 1996.

Scatter diagram

- S-R Helicity vs CAPE -



Hs-r = 150 to 299	Weak tornadoes
Hs-r = 300 to 449	Strong tornadoes
Hs-r > 450	Violent tornadoes
CAPE < 0	Stable
CAPE = 0 to 1000	Marginally unstable
CAPE = 1000 to 2500	Moderately unstable
CAPE = 2500 to 3500	Very unstable
CAPE > 3500 to 4000	Extremely unstable (capped?)

"Sweet Spot" :

- Hs-r of 250 - 400

- CAPEs 1500 - 3000

Wet Bulb Zero

The wet bulb temperature represents the lowest temperature a volume of air at constant pressure can be cooled to by evaporating water into it. The height of the wet bulb zero is that level on the sounding where the wet bulb drops to 0^0 C.

In general, WBZ heights from 5Kft to 12Kft are associated with hail at the ground.

The potential for large hail is highest for WBZ heights of 7Kft to 10Kft, with rapidly diminishing hail size below 6Kft and above 11Kft.

* Above 11Kft, hail is less common since it has a smaller depth in which to form and may melt before reaching the ground due to a deep warm layer below.

* WBZ values too low indicate shallow warm cloud depth with less warm cloud collision- coalescence occurring to provide necessary liquid drops to increase hail size.

The WSR-88D uses the height of the 0^0C and -20^0C isotherm in the Hail Algorithm.

We adjust this continually using either actual soundings or grid point soundings from the models. The RUC is very useful here. Slight adjustments to these numbers has a dramatic influence on Hail Size output from the 88D.

End Part 1

Part 2 - Tracking and Identifying Storms